Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

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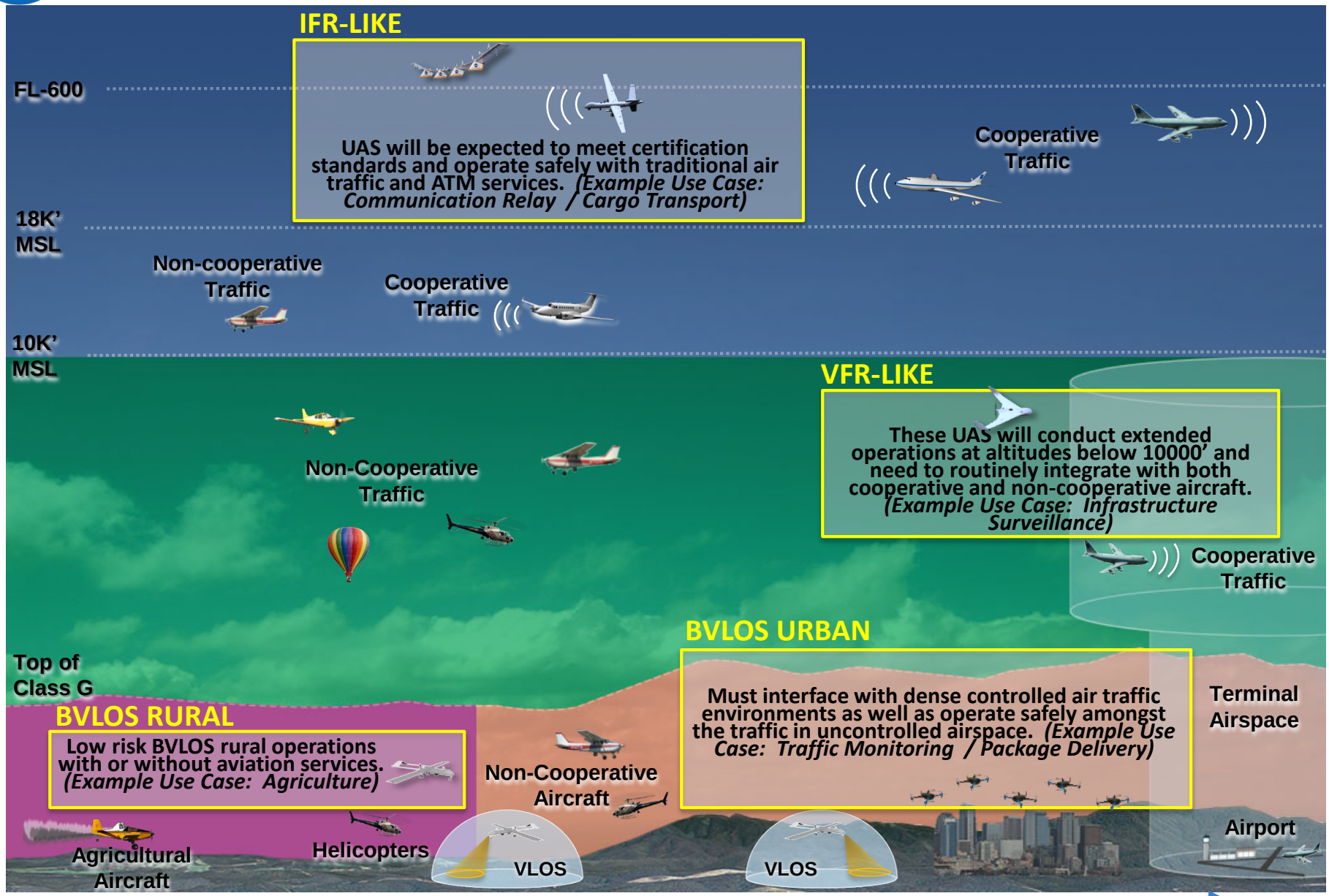
Chief Engineer

Full UAS Integration Vision of the Future

Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities

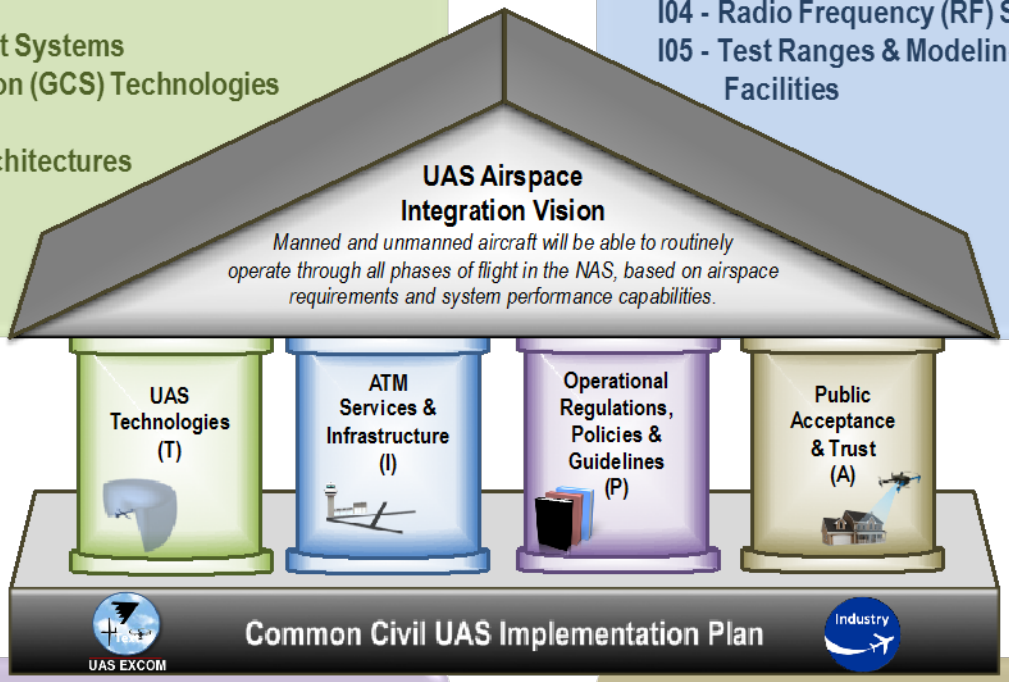
Emerging Commercial UAS Operating Environments (OE)



NASA UAS Airspace Integration Pillars and Enablers

UAS Technologies:
T01 - Airport Operations Technologies
T02 - Airworthiness Standards
T03 - Command, Control, Communications Technologies
T04 - Detect & Avoid (DAA)
T05 - Flight & Health Mngmt Systems
T06 - Ground Control Station (GCS) Technologies
T07 - Hazard Avoidance
T08 - Highly Automated Architectures
T09 - Navigation
T10 - Power & Propulsion
T11 - Weather Avoidance

ATM Services & Infrastructure:
I01 - Airport Infrastructure
I02 - Air Traffic Management (ATM) Infrastructure
I03 - Non-FAA Managed Airspace Infrastructure
I04 - Radio Frequency (RF) Spectrum Availability
I05 - Test Ranges & Modeling & Simulation (M&S) Facilities



Operational Regulations, Policies & Guidelines:
P01 - ATM Regulations / Policies / Procedures
P02 - Airworthiness Regulations / Policies / Guidelines
P03 - Operating Rules / Regulations / Procedures
P04 - Safety Risk Mngmt & Methods of Compliance

Public Acceptance & Trust:
A01 - Cyber Security Criteria & Methods of Compliance
A02 - Legal & Privacy Rules / Guidelines
A03 - Noise Reductions
A04 - Physical Security Criteria & Methods of Compliance
A05 - Public Safety Confidence

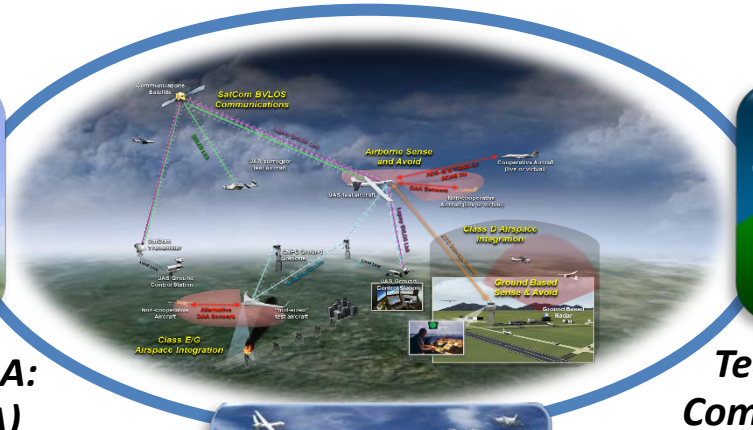
The UAS Airspace Integration Pillars enable achievement of the Vision

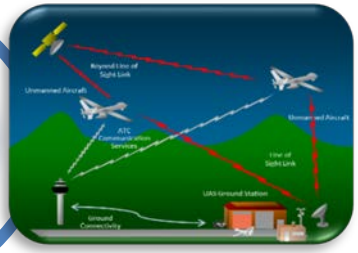
UAS Operational Concepts and Technologies

Project Goal

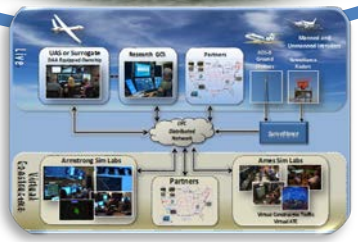
Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System

Technical Challenge-DAA: Detect and Avoid (DAA)





Technical Challenge-C2: Command and Control (C2)



SIO: System Integration and Operationalization for UAS (SIO)

UAS-NAS Phase 2
Project Organization Structure

PROJECT OFFICE LEVEL

Project Leadership

Project Manager (PM)	Robert Sakahara (Acting), AFRC
Deputy PM	Davis Hackenberg (Acting), AFRC
Deputy PM, Integration	Vacant
Chief Engineer (CE)	William Johnson, LaRC

Project Support: Project Planning & Control

Lead Resource Analyst	April Jungers, AFRC
Resource Analysts	Amber Gregory, AFRC
	Warcquel Frieson, ARC
	Julie Blackett, GRC
	Pat O'Neal, LaRC
Scheduler	Irma Ruiz, AFRC
Risk Manager	Jamie Turner, AFRC
Change/Doc. Mgmt	Lexie Brown, AFRC
Admin Support	Sarah Strahan, AFRC

Project Support: Technical

Deputy CE	TBD, TBD
Staff Engineer	Dan Roth, AFRC

SUBPROJECT LEVEL

Command and Control (C2)

Subproject Manager

Mike Jarrell, GRC

Subproject Technical Lead

Jim Griner, GRC

Detect and Avoid (DAA)

Subproject Manager

Jay Shively, ARC

Subproject Technical Lead

Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

Integrated Test and Evaluation (IT&E)

Subproject Manager

Heather Maliska, AFRC

Subproject Technical Lead

Jim Murphy, ARC; Sam Kim, AFRC

ELEMNET/ TWP LEVEL

Technical Work Packages (TWP): Terrestrial Extensions, Ka-band Satcom, Ku-band Satcom, C-band Satcom

Technical Work Packages (TWP): Alternative Surveillance, Well Clear, ACAS Xu, External Coordination, Integrated Events

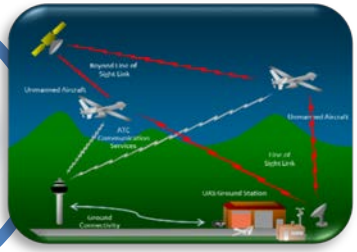
Technical Work Packages (TWP): Integration of Technologies into LVC-DE, Simulation Planning and Integration, Integrated Flight Test

DAA: Detect and Avoid

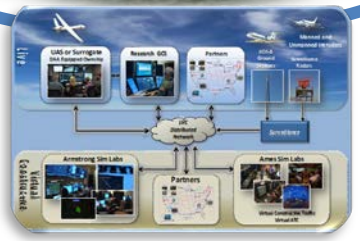
TC-DAA

Develop Detect and Avoid (DAA) operational concepts and technologies in support of standards to enable a broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to detect and avoid manned and unmanned air traffic

Technical Challenge-DAA: Detect and Avoid (DAA)

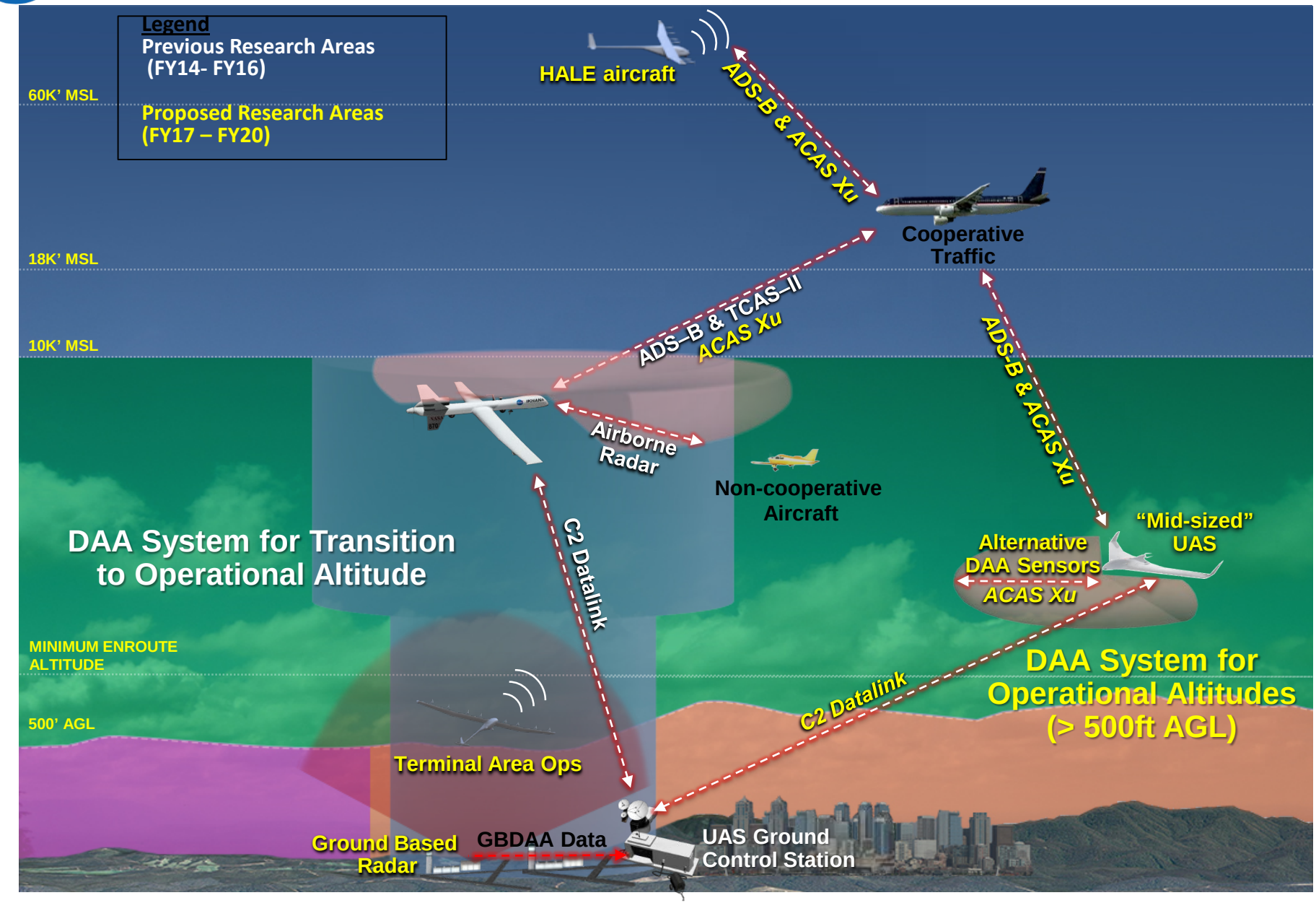


Technical Challenge-C2: Command and Control (C2)



SIO: System Integration and Operationalization for UAS (SIO)

Detect and Avoid (DAA) Operational Environments



DAA: Overview

Description: The Detect and Avoid (DAA) effort will work with the Unmanned Aircraft System (UAS) community through **concepts and technology development** of DAA technologies applicable to a **broad range of aircraft with low cost size, weight, and power (SWaP)** availability. The DAA system will **detect** other aircraft in their vicinity, **predict** if the aircraft trajectories will be in conflict with each other, and **determine the appropriate guidance** to display to the UAS pilot in command. Pilot responses to the system will be assessed in order to **validate standards** being developed for UAS **within RTCA SC-228**. Robust safety and collision risk assessments, algorithm development, and ground control station display development will be performed in **collaboration with other government agencies and industry stakeholders** to support the broad needs of detect and avoid for the UAS community.

Objectives

- **Develop and validate UAS DAA requirements** for Low-SWaP airborne DAA systems to support standardization through the evaluation of commercial and engineering prototype DAA systems that enable a broader set of UAS operations
- **Implement** state of the art **DAA technologies** into an UAS and test in operationally relevant scenarios
- Obtain FAA approval to **demonstrate** SC-228 **Phase 1 DAA MOPS technologies** on an unmanned aircraft in the NAS as an alternative means of compliance to FAR Part 91 “see and avoid” rules (i.e. No Chase COA)

Approach

- **Develop Concept of Operations and performance standards** in coordination with RTCA and FAA
- **Solicit industry partnerships** to develop DAA technologies
- **Perform modeling and simulation to Characterize the trade space of the DAA system** for critical areas
- **Flight Test and V&V** of DAA technologies for performance standard requirements, and DAA system technology builds
- Leverage Phase 1 DAA MOPS developed technologies to **obtain FAA approval to fly the DAA system in the NAS** with as few restrictions as possible (No Chase COA)

Deliverables

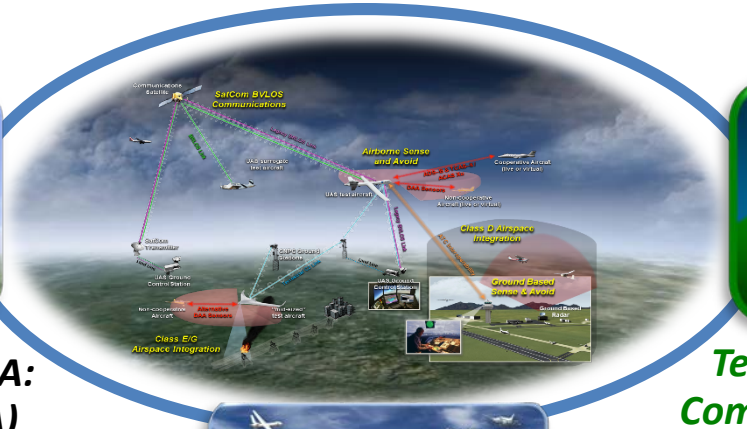
- RTCA Standards Inputs:
  - DAA Phase 2 MOPS
  - Sensor Phase 2 MOPS
  - ACAS Xu MOPS
- Technical papers & presentations to technical and regulatory organizations
- Candidate DAA guidance, displays, & alerting
- Integrated design documents for each integrated event

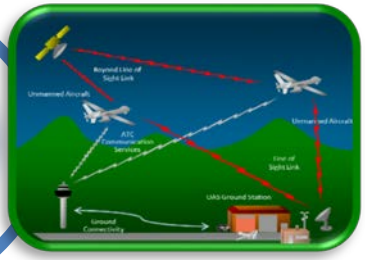
C2: Command and Control

TC-C2

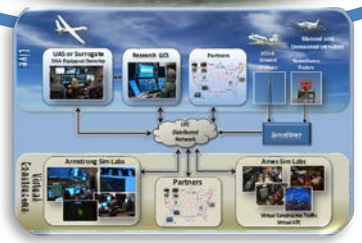
Develop Command and Control (C2) operational concepts and technologies in support of standards to enable the broad range of UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations and are required to leverage allocated protected spectrum

Technical Challenge-DAA: Detect and Avoid (DAA)



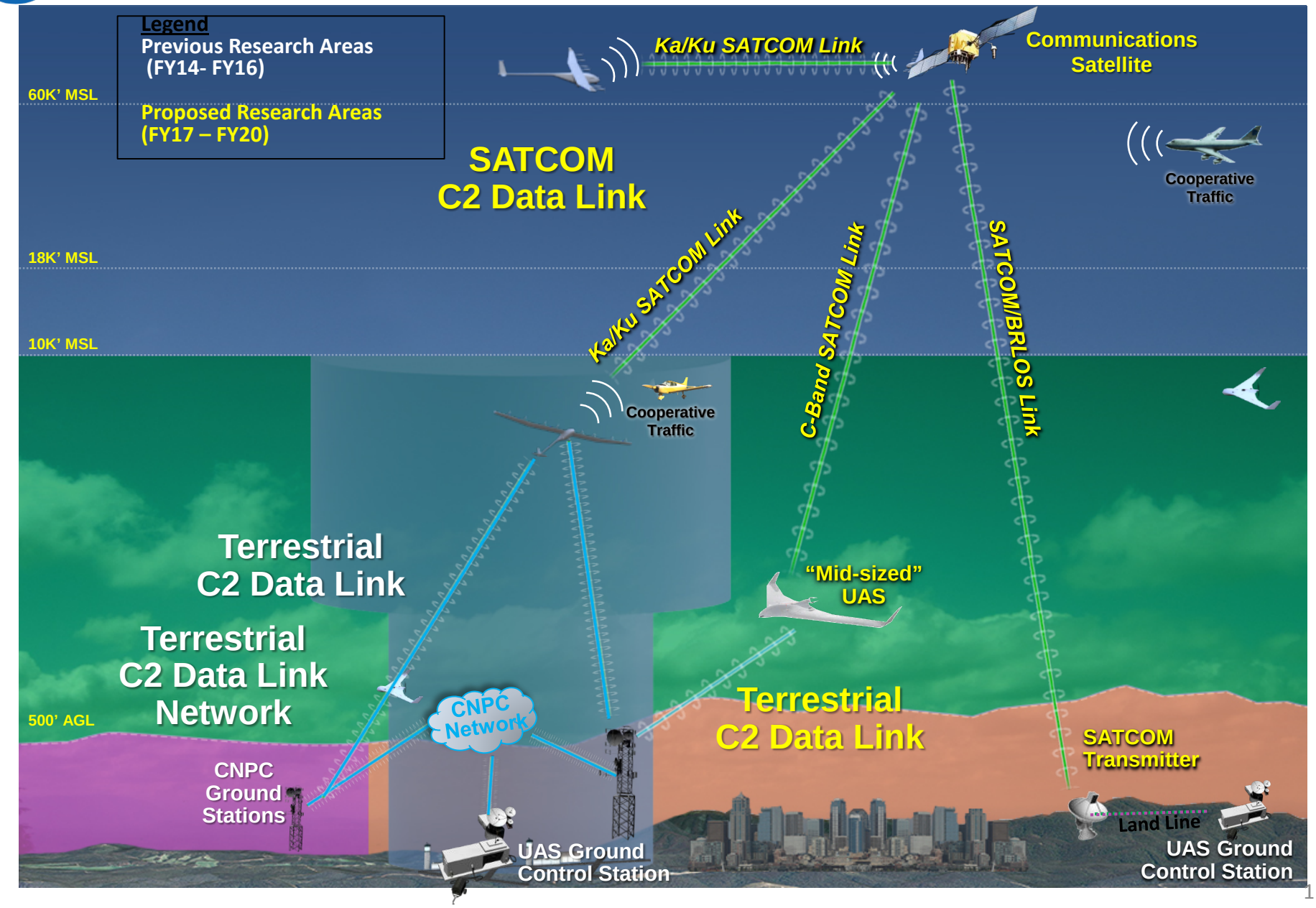


Technical Challenge-C2: Command and Control (C2)



SIO: System Integration and Operationalization for UAS (SIO)

Command and Control (C2) Operational Environments



TC-C2: Overview

Description: The Command and Control (C2) effort will work with the UAS community on **concept and technology development** of C2 systems that are consistent with **national regulations, standards, and practices**. C2 will **develop and analyze robust datalinks in designated spectrum** and propose **security recommendations for civil UAS** control communications. All of the identified activities will be accomplished by **collaborating with other government agencies and industry partners** to address the technical barriers.

Objectives

- **Develop and validate UAS C2 requirements** to support C2 standardization through the evaluation of engineering prototype **Networked C-Band Terrestrial** radio systems
- **Develop and validate UAS C2 requirements and radio spectrum allocation decisions** to support C2 standardization through the evaluation of commercial and engineering prototype **Ka/Ku Satcom** radio systems
- Provide **system design studies** (payload and earth station) and system design requirements of **C-band Satcom** systems for C2 standardization

Approach

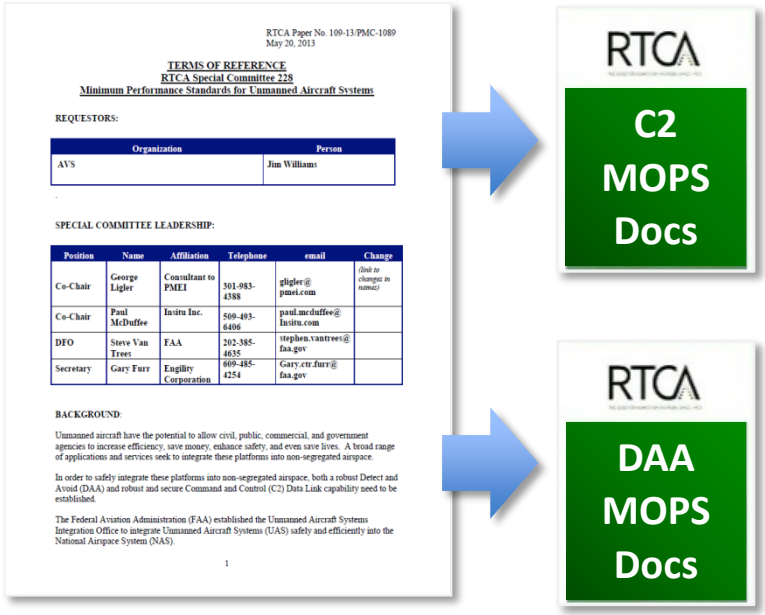
- **Develop Concept of Operations** to be leveraged for initial requirements for C2 partnerships, and coordination with RTCA and FAA
- Jointly **develop performance standards** with RTCA and FAA throughout lifecycle of concept and technology development
- **Solicit industry partnerships** to develop radio technologies
- **Flight Test and V&V** of radio technologies for performance standard requirements, and radio technology builds

Deliverables

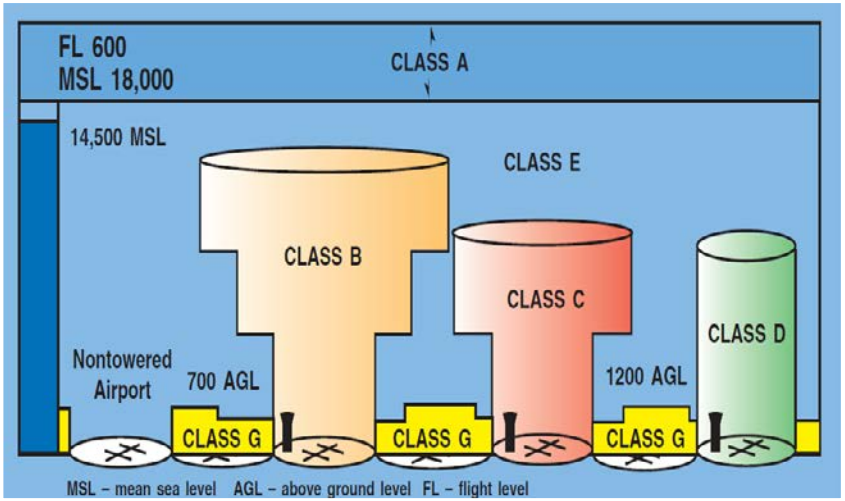
- RTCA Standards Inputs
  - CNPC Link MASPS
  - CNPC Link MOPS
- Technical papers & presentations to technical and regulatory organizations

RTCA SC-228 Phase 2 MOPS Terms of Reference

- RTCA SC-228 ToR defined a path forward to develop MOPS
  - Phase 2 MOPS included in the original ToR, but had several TBDs
  - ToR development team defined Phase 2 DAA and C2 scope broad enough to fully enable the operating environments for relevant UAS (e.g., instrument flight rules [IFR] and visual flight rules [VFR]-like)
- Phase 2 MOPS ToR scope
  - C2: Use of satellite communication (SATCOM) in multiple bands and terrestrial extensions as a C2 data link to support UAS and address networking interoperability standards for both terrestrial and satellite systems
  - DAA: Extended UAS operations in Class D, E, and G, airspace, and applicability to a broad range of civil UAS capable of operations beyond visual line of sight (BVLOS)



RTCA SC-228 ToR



System Integration and Operationalization (SIO) for UAS

SIO: System Integration and Operationalization for UAS

Integrate state of the art DAA and C2 technologies into Unmanned Aircraft Systems (UAS) to ensure sufficient aircraft level functional and operational requirements, and perform demonstrations in the NAS to inform Federal Aviation Administration creation of policies for operating UAS that have Communication, Navigation, and Surveillance (CNS) capabilities consistent with IFR operations

- Definition of "Operationalization"
  - A process for measuring operational concepts with empirical methods, particularly concepts that are complex and difficult to measure without empirical data
    - *Bridgman, P.W. (1927). "The Logic of Modern Physics"*
- NASA's UAS-NAS Project use of "Operationalization"
  - A process to mitigate one or more implementation barriers by addressing one or more of the UAS Airspace Integration Pillars and Enablers through TRL 6+ demonstration/testing in an operationally relevant environment

Summary

- UAS-NAS Project has developed significant capabilities and infrastructure for the development of DAA, non-cooperative surveillance sensor, and C2 technologies
- Significant work remains ensuring DAA and C2 technology are interoperable with the entire National Airspace System
- Project is dedicated to driving the community toward robust and innovative solutions that apply to DAA, C2, and other necessary vehicle technologies

Questions?

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